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ABSTRACT

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RIR-77-1

INSTRUCTIONAL DESIGN IN CAI

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ABSTRACT

A conceptual framework for instructional design is introduced which includes three major components: task analysis, learner analysis, and means analysis. Task analysis involves dimensions such as objectives, skills and subject matter structure. Learner analysis is concerned with variables such as age, population and group characteristics, and individual differences. Means analysis involves the selection of instructional strategies, techniques of evaluation and feedback, and media. An instructional design cycle is discussed which illustrates how these three components fit into an overall educational context. This framework is then used to consider the application of instructional design to CAI activity.

I. An Introduction to Instructional Design

This first section provides a brief introduction to and overview of instructional design. It presumes no prior knowledge of the topic nor any technical background in education. Subtopics covered are the purpose of instructional design; differences between instruction, teaching, and learning; the three major aspects of instructional design; and the major stages of the instructional design cycle. The reader who wishes to study the topic in further detail should consult one of the many good books available on the topic (e.g., Davis, Alexander & Yelon, 1974; Gagne & Briggs, 1974; Kemp, 1971; Merrill, 1971).

1. What is Instructional Design, Anyway?

One way of interpreting this question is "What is it about?". The purpose of instructional design is to produce more effective learning. It attempts to achieve this purpose by the specification of environmental conditions/situations which will lead to more effective learning. It involves an attempt to define as precisely as possible, what constitutes "effective" learning. It should be clear that instructional design is based upon the assumption that more effective learning is a desirable goal, and further, is worth the costs and commitment of resources which such an effort entails. Anyone who rejects this goal, either wholly or in part, will have little use for instructional design.

It will help to define instructional design by contrasting instruction with teaching and learning. The notion of instruction may seem to be synonymous with that of teaching. While instruction and teaching are intimately related, they are not the same thing. First of all, as an activity, teaching is much broader than instruction. Teaching involves numerous clerical and administrative duties, classroom management, informal student counseling and guidance, and a host of other functions which do not directly pertain to learning. Instruction, on the other hand, focuses quite narrowly on factors directly affecting learning. Secondly, instructional design is a systematic activity. In contrast to the intuitive "fly by the seat of your pants" type of decision-making typically involved in teaching, or the "rule of thumb" procedures taught in teaching methods courses, instructional design attempts to formulate principles of instruction which when followed exactly, will work reliably and in a reproducible fashion. The ultimate goal of instructional design would be to formulate a theory of instruction which specifies for a given student and learning task, the optimal manner in which

to instruct.[1]

In addition to the systematic nature of instruction, there is a third major characteristic which distinguishes instruction from teaching. This is the fact that instructional design is an empirical approach to instruction. It is certainly true that most teachers have always tried to <u>think</u> out the ways to produce effective learning. This is a rational and intuitive orientation to instructional effectiveness. Instructional design involves considerable attention to the monitoring and measurement of instruction by precise means. Instruction is evaluated and improved through an empirical approach. In the instructional design cycle (which we will discuss later), research is an integral part of the delivery of instruction.

Learning is the intended outcome and criterion of instructional design. Because of this, it would seem that a theory of learning and a theory of instruction should be one and the same. This is not the case, however. The study of learning is a descriptive enterprise, the goal being to describe the processes by means of which behavior is permanently altered. Today, the study of learning focuses primarily on the mental or cognitive aspects of learning -- what changes go on in the thinking processes. Instructional design, however is prescriptive rather than descriptive in nature. It attempts to formulate principles which specify or dictate how to manipulate the environment so that effective learning will occur.[2] Furthermore, learning theory involves the fundamental search for basic laws which describe learning processes in all their forms and manifestations. Instructional design is an applied science (educational engineering, if you like), and is essentially concerned with the establishment of principles which can be used under well-defined conditions to produce effective learning. While a theory of learning and a theory of instruction must

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1. For some suggestions about what such a theory of instruction might look like, see Atkinson (1972), Bruner (1967), Di Vesta (1972), or Gropper (1976).
2. The prescriptive nature of instruction, particularly the idea of "manipulating the learner's environment" often raises the misconception that instructional design is an anti-humanistic affair. This is patently wrong. Nothing could be more <u>genuinely</u> humanistic than an overall goal of allowing each individual to learn most effectively and hence realize their full personal potential. Furthermore, for certain subjects and learners, the only "manipulation" required may be to provide a suitably rich learning situation and adequate resources.

ultimately be mirror images of each other, they represent two different figure-ground perspectives.

To summarize, then, the purpose of instructional design is to produce effective learning via the optimal arrangement of environmental conditions. Instructional design is closely related to teaching and learning but it differs from these in that it is systematic, empirical and prescriptive in nature.

2. What is Instructional Design, Anyway?

Another way of construing the question is in the form of "What does it involve?". Instructional design can be divided into three major aspects: task analysis, learner analysis, and means analysis. Each of these three aspects encompasses a domain of major instructional dimensions. A comprehensive instructional design will involve the dimensional interaction of these three domains. Figure 1 is a conceptual model which illustrates the interaction of the major dimensions of instructional design.

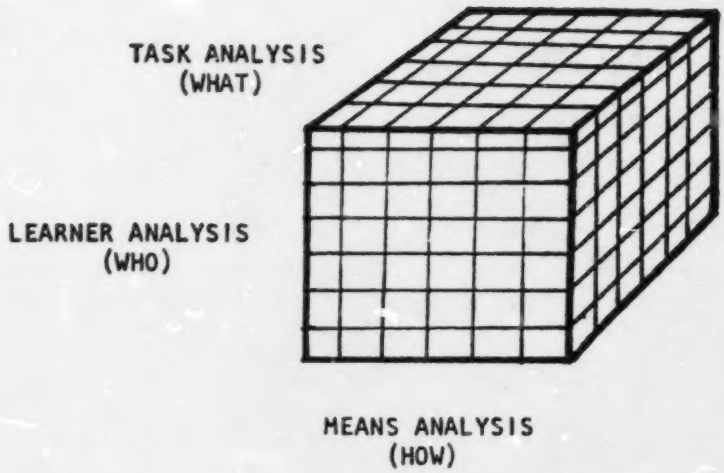
Insert Figure 1 about here

Task analysis is concerned with the "what" dimensions of instruction. The analysis of "what" dimensions is closest to what has traditionally been subsumed under the rubric "curriculum design". It involves the analysis of the characteristics of different subject matters (e.g., history versus mathematics), the particular structure of one subject (e.g., arithmetic versus topology), as well as general variables such as difficulty levels, step sizes, inherent logics and sequences, hierarchial organization, etc. All of these variables deal with the <u>content</u> of a task or subject. Ausubel (1968, Chapter 9) discusses these characteristics in terms of the role they play in the meaningful structure of a subject matter.

A second and very important component of task analysis is the specification of instructional objectives. In fact, task analysis is often taken to be synonymous with this dimension. While there are many differing conceptions of exactly how objectives should be specified (see Davies, 1973), it is generally agreed that they should define the expected behavior of a learner after instruction has occurred. Only if the objectives were clear and explicitly stated is it possible to determine if learning actually occurred and assess how effectively. For this reason, the formulation of objectives for a particular task or subject is crucial to the overall success of instructional design. The specification of objectives usually, but not always,

FIGURE 1

MAJOR DIMENSIONS OF INSTRUCTIONAL DESIGN



indicates the situation or context of instruction. Is this instruction which is to be conducted in the classroom or is it on the job training? Is the task to be learned for illustrative purposes or is it to be actually performed? The proper specification of the context is important because this is the context in which the learning will be assessed. It is clearly instructional folly to teach a task in one context and test in another.

Finally, task analysis involves the specification of the skills or abilities which are required by a particular task or subject. In order to specify the nature of instruction needed, one must be able to specify what types of abilities (e.g., cognitive, affective, psychomotor) are involved and what levels. Taxonomies of learning outcomes (e.g., Bloom, 1956; Gagne, 1970) are valuable tools in the identification of levels of skills and abilities.

Learner analysis is concerned with the "who" dimensions of instruction. The analysis of "who" dimensions is necessary because instruction will be different for different types of learners for the same task or subject. While a number of different approaches to learner analysis have developed in the past (see Schwen, 1973), a systematic learner analysis methodology for instruction does not really exist at present.

A rather broad and encompassing "who" dimension is the pre-entry skills or behavior of the learner. Any instruction makes certain assumptions about the skills and abilities which the student already possesses. Failure to possess these assumed skills will almost certainly prevent the learner from benefiting from the instruction and achieving the desired learning objectives. A fairly simple example involves the understanding of instructions provided for a task. A student who lacks the necessary reading or comprehension ability to understand the instructions clearly cannot progress very far on the task. Because most tasks involve a hierarchial organization of dependent steps, failure to possess the necessary skills will eventually produce inefficient learning.

One major learner analysis dimension is age. Developmental theories (e.g., Piaget, Bruner, Kolberg, Werner) all suggest that the availability of certain abilities and skills is an age dependent phenomenon. This means that the design of instruction must be arranged with such developmental sequences in mind. It must be determined whether or not the required skills for a task or subject are typically available at the age level of the students. Conversely, the design of instruction should take advantage of the particular skills or abilities available to the

learner at a particular age. Things other than abilities change with age also; the nature of motivations, attitudes, curiosity and learning sophistication all change with age.

Another dimension of learner analysis is the population or group characteristics of the learners. This aspect of learner analysis is most evident in the design of instruction for learners with physical or mental handicaps or disabilities. It is also of obvious concern when the instruction is designed to span cultural barriers such as instruction intended for native students. Within any particular population, there are certain subgroups (e.g., poor "inner city" students versus affluent suburban students) with differences in abilities, motivations, attitudes, etc., which will require particular attention.

Individual differences are a well studied (but still poorly understood) dimension of learner analysis. Here we are concerned with differences between individuals which necessitate different instructional methods to produce equally effective learning on the same task. This includes differences in aptitudes, abilities, styles, and personality traits. Since individualized instruction is a major concern of instruction design, a sophisticated knowledge of the ways individuals differ in learning is important.

Means analysis is concerned with the "how" dimensions of instruction. The problem here is to determine what processes or procedures are necessary to teach certain types of learners and tasks. While means analysis is a very important aspect of instructional design, little systematic attention has been devoted to a theory of instructional means. This is mainly because instructional ends (goals, objectives) have traditionally been emphasized. However, Olson (1976) has some cogent remarks on this point:

> My conclusion is that the means of education have had a more important effect on the development of mental competencies and on the literate bias of the culture than we have here-to-fore realized. Choice of <u>means</u> must be as rational and reflective a process as the choice of <u>ends</u>...Education must recognize that while the content chosen makes some contribution to knowledge, the means of instruction chosen recruits and makes some contribution to the child's intellectual skills. (p. 34, original italics).

Existing research in means analysis has mostly been devoted to the comparative study of different media. This research has attempted to compare the relative effectiveness of one media over another (e.g., TV versus films) as well as the best ways of utilizing a particular media. This line of research has led to the formulation of media taxonomies (e.g., Clark, 1975; Heidt, 1975) indicating when to use what

media.

The specification of instructional strategies or modes is another major dimension of means analysis. This involves the selection of macrostrategies such as group versus individual instruction or expository (tutorial) versus exploratory (socratic) modes, and microstrategies which include the use of techniques such as shaping, fading, prompting, and so on, within any particular macrostrategy.

Student evaluation is another major dimension of means analysis. In designing evaluation, a selection must be made between the major types possible (e.g., criterion-referenced, domain-referenced, norm-referenced) in terms of the nature and type of feedback that will best aid the learner. Evaluation will also affect the difficulty, sequence, and step size of the instruction, remedial or enrichment segments, etc.

A further dimension of means analysis is motivational variables. Ways of maintaining the interest and attention of the learner must be designed if learning is to take place. Reinforcement theory provides ideas and guidance for maintaining motivation. Humor and novelty are devices also used to maintain motivation. The appropriate "mental set" may facilitate learning, an inappropriate one may inhibit it. Certain means may be used for their motivating properties which enable learning to occur even though they do not directly contribute to learning.

Task, learner and means analysis are the three major aspects of instructional design. However, instructional design (and hence effective learning) is the result of interaction between these three aspects as depicted in Figure 1. Analysis of the task, learner and means dimensions is actually carried out in terms of their interaction; the separation of the dimensions is merely a conceptual one for the purposes of discussion. Thus, one studies the differences in abilities or skills across age so that one can determine what instructional strategies will be optimal for learners of those different ages. One is concerned with the individual and population differences for a certain subject matter so the appropriate motivating conditions can be arranged. Different subject matters may be most effectively presented via certain media. And so on. Instructional design is primarily concerned with understanding the complex interaction of "what", "who" and "how" dimensions to produce effective instruction.

3. What is Instructional Design, Anyway?

A third way of interpreting this question is, "What kind of activity is it?". Instructional design as an activity involves five major phases. These are best described in terms of stages in an instructional design cycle. An idealized instructional design cycle is shown in Figure 2.

Insert Figure 2 about here

The initial stage in this cycle involves the identification of educational needs and goals. From society at large, or perhaps more local contacts, certain educational needs or goals are discerned. These may range from the exceedingly nebulous (e.g., the transmission of cultural heritage, realization of self-potential) to those which are more specific and task-oriented (e.g., reading or spelling proficiency, ability to manage a business). This first step in the instructional design cycle involves the translation of such goals from the overall system into goals within the educational system. This may or may not involve the opinion of the instructional designer as to the validity of these goals and needs.

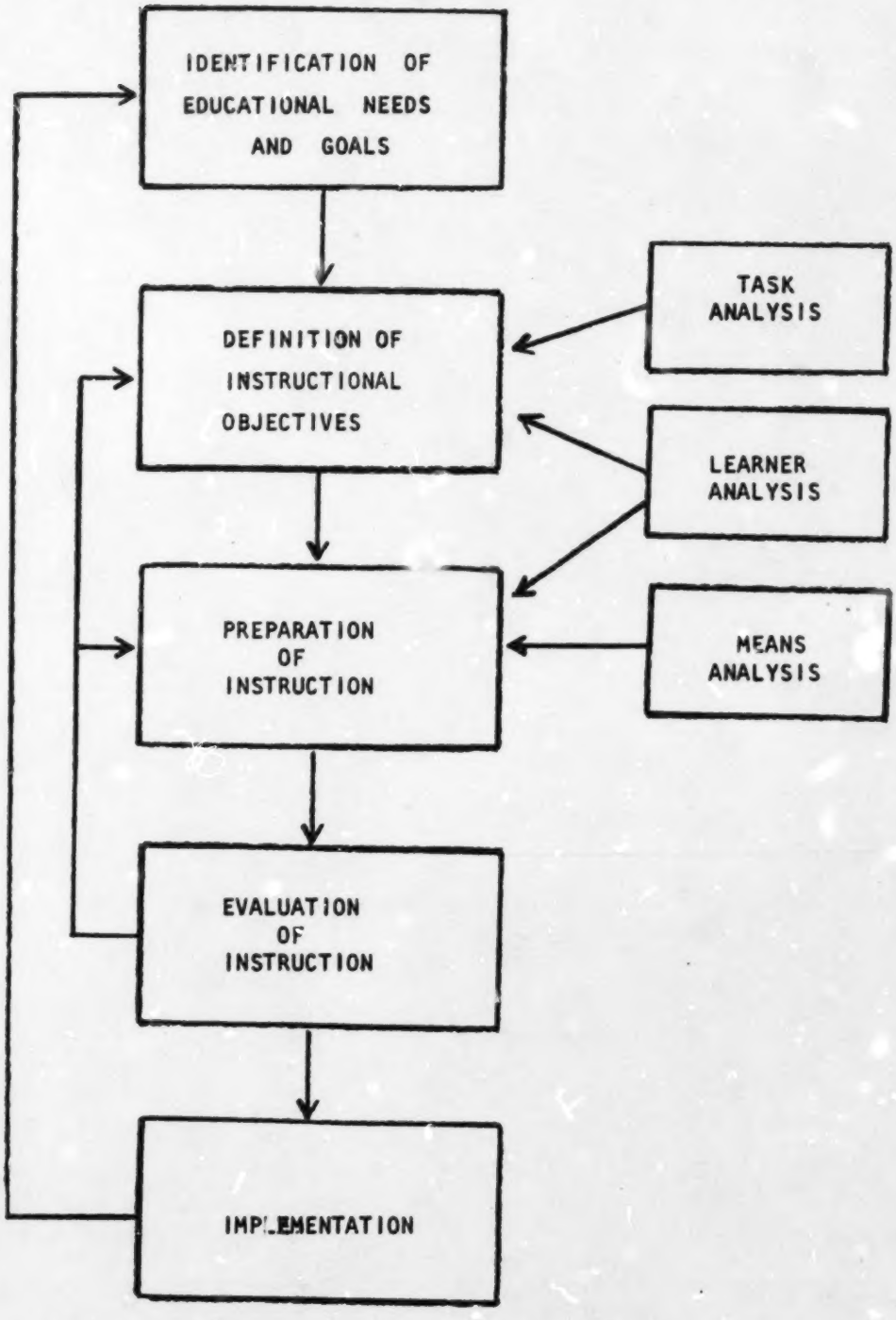
The second stage of the cycle involves the definition of instructional objectives. This means that educational goals must now be translated into objectives which can be learned. At this point, task and learner analysis are involved to determine the relevant dimensions of the task (one of which is the objectives) and the characteristics of the learners involved. This stage typically involves a specialist in the subject matter or task concerned and someone experienced with the particular population/group of learners.

Assuming that the goals have been successfully formulated into specific objectives, the next stage involves the actual preparation of instruction. This involves learner and means analysis to determine the appropriate "how" dimensions for the particular task and learners. This stage will typically involve media specialists in the actual formulation and production of instruction. Having accomplished the preparation, the instruction is carried out as prescribed.

The delivery of instruction leads to the next stage, evaluation of instruction. This is truly the empirical phase of instructional design. Such evaluation will typically be of two kinds, formative and summative. Formative evaluation is the assessment of the effectiveness for the purpose of

FIGURE 2

INSTRUCTIONAL DESIGN CYCLE(S)



forming better instruction. This type of evaluation is most concerned with finding out if the selected instructional means are resulting in the learning of the specified objectives for all students. Clearly, the measurement must be sensitive if it is to provide useful information on the instructional inadequacies and gaps. The results of formative evaluations are used to revise the instructional means or possibly the instructional objectives. This is the first type of instructional recycling which goes on in an instructional design cycle.

The second type of evaluation is called summative evaluation. The purpose of summative evaluation is to sum up the effectiveness of instruction in terms of a comparison with other existing methods of achieving the same objectives. It also involves the tabulation of any positive or negative outcomes which were not anticipated or included in the specified objectives. Summative evaluation is typically more formal and rigorous than formative evaluation and attempts to provide definitive answers to educational decision-makers regarding the acceptability of the studied form of instruction. It is common for this stage to involve measurement and evaluation specialists who are essentially independent of the previous instructional design work.

The "final" stage of the instructional design cycle is the implementation of instruction which has been judged effective. At this point all formal and planned evaluation has been completed and the steps now involve the dissemination and distribution of the instructional method or product. This may involve the local or widespread use of the instructional product and may involve commercial marketing. The "new" instructional method now becomes the standard. This sets the stage for the second major type of instructional recycling, between the implemented product and educational needs and goals (the first stage of the cycle). The implementation of an instructional method may well cause the redefinition of educational goals and needs which initiates a new turn of the cycle. Instructional design is inherently an iterative procedure. In actuality, it has no real end, no final state. For this reason instructional design must be understood as a process of continual change and innovation.

II. Applying Instructional Design to CAI

This section considers some specific task, learner, and means variables in the context of the design of CAI materials. It assumes a reasonable familiarity with current CAI systems and terminology. Since the overall problem is to determine when a particular means variable is appropriate (or when it is not) with respect to differences in task and learner variables, the discussion of task and learner dimensions will be in terms of their relationship with the "how" dimensions of instruction. While this discussion is primarly concerned with the instructional capabilities of current CAI systems, some mention is made of future needs and possibilities.

1. Task Variables in CAI.

Beginning with the task variables (the "what" dimensions), consider the relationship between the type and level of skills to be learned and the major types of macrostrategies used in CAI. Table 3 shows the relationships between Gagne's (most recent) learning categories and 7 major instructional strategies. [3]

Insert Figure 3 here.

The "X" marks indicate that a certain strategy is suitable or appropriate for a particular category of learning outcome. Verbal information (involving the memorization and recall of facts, details) is most appropriately presented via a tutorial (i.e., expository) strategy and tested via a drill & practice strategy. Discrimination learning (identification/recognition) can be presented via a tutorial or simulation strategy and can be tested by drill & practice or simulation strategies (depending upon the sophistication of the discrimination). Concepts (involving categorization or classification) can be presented by tutorial or exploratory strategies depending upon whether the desired mode is expository and teacher-controlled or self discovery and student-controlled. The value of exploratory strategies has been extolled by Papert & Solomon, 1972 (LOGO), Pelee, 1974 (APL) and Dwyer, 1974 (BASIC).

Principle (rule) learning can also use either tutorial or exploratory strategies as well as simulation and socratic

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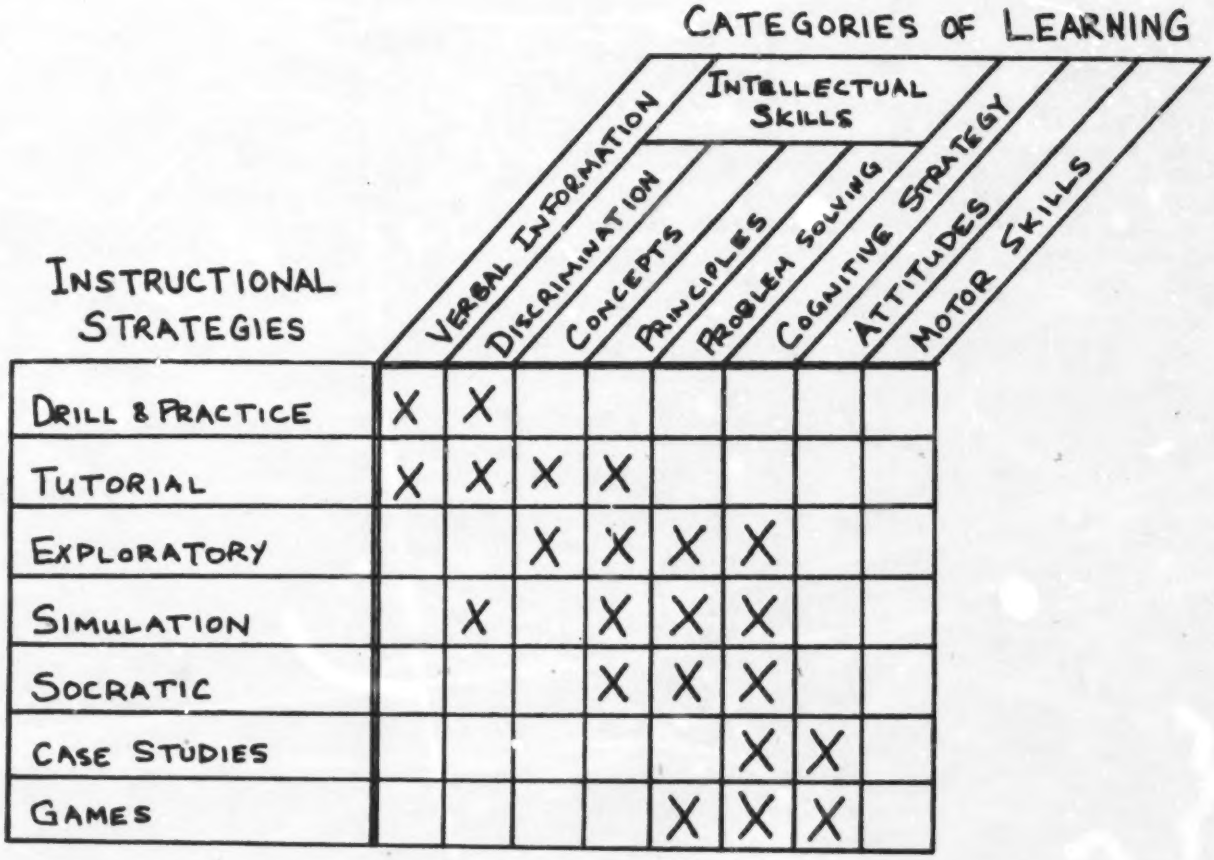
3. The details of these learning categories are given in Gagne & Briggs (1974). Appendix I describes each of the 7 strategies shown.

FIGURE 3



INSTRUCTIONAL STRATEGIES	VERBAL INFORMATION	DISCRIMINATION	CONCEPTS	PRINCIPLES	PROBLEM SOLVING	COGNITIVE STRATEGY	ATTITUDES	MOTOR SKILLS
DRILL & PRACTICE	X	X						
TUTORIAL	X	X	X	X				
EXPLORATORY			X	X	X	X		
SIMULATION		X		X	X	X		
SOCRATIC				X	X	X		
CASE STUDIES						X	X	
GAMES					X	X	X	

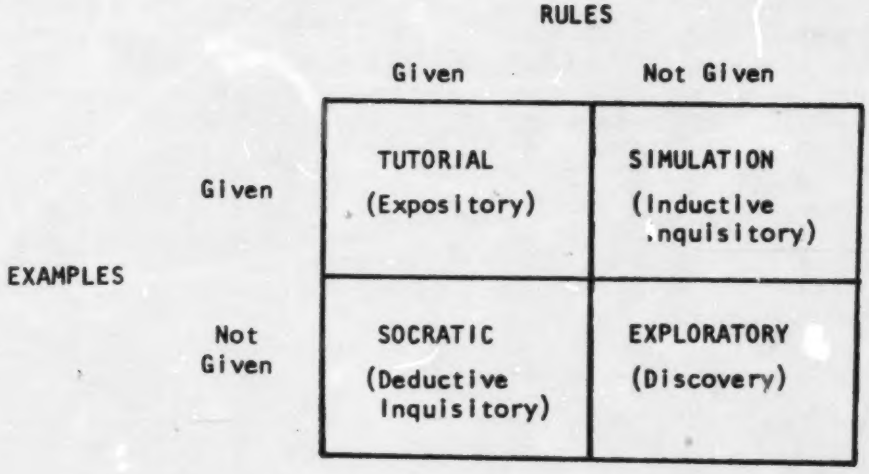
(dialogue) strategies. Principle learning involves the learning of both rules and examples of their application. They can be taught in the four ways illustrated in Figure 4.

Insert Figure 4 here.

Thus, the presentation of both rules and instances is an expository strategy and would be done via a tutorial strategy; presenting instances and expecting the student to induce the rule or vice-versa are examples of socratic or simulation strategies; and requiring the student to induce both rules and instances is an example of discovery learning and an exploratory strategy is appropriate. To give a concrete example, if we are teaching the programming concept of recursion, we could present both the rule and suitable examples (probably contrasting it with iteration) following a tutorial strategy; we could provide the rule and ask the student to deduce an example or give some examples and have the student induce the rule either via a simulation or socratic dialogue; or we could teach the student a recursive language like LOGO and allow the student to discover the idea of recursion without any explicit instruction. The suitability of these possibilities will depend upon the particular learners, the nature of the task, and the pedagogical biases of the instructional designer.

Problem solving skills (the derivation of higher-order rules) is probably best taught using exploratory or socratic strategies or via simulations or games. The important thing is that students actually try to solve problems themselves rather than being shown. Each of these strategies is particularly appropriate for certain subjects and learners. Simulations are quite frequently used in subjects where a realistic context is important (e.g., medical or pilot training). Games are typically very motivating and hence suitable for use with young children or students with relatively little background in a subject. Exploratory strategies are appropriate when the learner is capable of directing the course of inquiry or when this is an object of the instruction. This latter skill is close to the learning of a cognitive strategy (the generation of problems/questions and methods of solution) and to creative abilities. Cognitive strategies are best taught via exploratory or socratic strategies, case studies, simulations or games. Once again, the particular choice of strategy will depend upon the learner and the task. For example, learning strategies appropriate for diagnostic activities (e.g., medicine, counselling) are probably best taught via case studies while learning strategies appropriate for scientific research (as in physics or chemistry) are likely best done with simulations. The learning of attitudinal skills is most appropriate for games

FIGURE 4


RULES
Given
Not Given
EXAMPLES
Given
Not Given
TUTORIAL
(Expository)
SIMULATION
(Inductive
nquisitory)
SOCRATIC
(Deductive
Inquisitory)
EXPLORATORY
(Discovery)

or case studies in which evaluative or choice behavior is the major type of student response. Finally, none of the strategies listed are appropriate for the instruction of motor skills (except for the obvious skill of typing at the keyboard) and in fact standard CAI systems are not appropriate for the teaching of such skills. [4]

As mentioned earlier, the 7 strategies just discussed are macrostrategies. Numerous microstrategies can be used with any particular macrostrategy. However, there are certain interdependencies between the micro and macrostrategies. For example, techniques such as prompting, shaping, or fading have one meaning in drill & practice or tutorial strategy but a slightly different meaning in a socratic strategy. Questioning styles in a tutorial strategy usually fulfill a testing or evaluative purpose; in a socratic strategy they typically serve a guiding or cueing role. The type of student feedback will likely consist of correct/incorrect messages in a tutorial strategy but the actual process results in a simulation or exploratory strategy. The general point here is that it is difficult to prescribe the appropriate use of microstrategies apart from the use of macrostrategies.

The usefulness of Figure 3 is to prescribe certain appropriate CAI strategies for the various skills required in a task or subject. It should be evident that any large amount of material will involve many different skills and hence various combinations of these strategies at different places. The basis for the pairing of certain strategies and skills is the knowledge that the major processes used in a certain strategy are the same underlying processes required for the matching skill. Because our understanding of exactly what these processes are is still crude, the prescriptions given in Figure 3 are correspondingly rough and in need of much further refinement.

To some extent, the choice of a particular strategy will determine the possibilities for the sequencing of a task. Thus, the choice of an exploratory or socratic strategy puts the control of task sequence more or less in the hands of the student. If a tutorial strategy is used, there is a need to plan the order in which tasks should be arranged. Such sequencing should follow a hierarchial

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4. The conceptual components of motor skills can still be taught via CAI however. Actually, CAI could possibly teach motor skills if apparatus was specially designed for this purpose (e.g., driving or flying simulators, swimming mounts, writing plates, etc)

organization with respect to the complexity of the skills involved. In terms of intellectual skills only, the appropriate general sequence is discriminations, concepts, principles, and problem solving. For a general discussion of sequencing in instructional design, see Briggs (1968).

While the selection of appropriate macrostrategies and their sequencing should be based upon the specific skills as revealed via a task analysis, it is possible to make some generalizations about types of subject matter. Certain subjects or tasks are algorithmic in nature (e.g., mathematics, programming, most physical sciences) and hence are particularly appropriate for generative logics (see for example, Uttal et al, 1970; Koffman & Blount, 1976). Since they tend to emphasize problem solving and cognitive strategies, they will rely heavily upon simulation, exploratory, and game strategies. Many social and natural sciences (e.g., geography, history, philosophy, literature, sociology, biology, etc.) on the other hand, involve mostly verbal information and concept learning skills and will therefore depend mainly upon tutorial, socratic and case study strategies. [5]

To summarize this discussion of task variables, it is emphasized that certain instructional strategies and sequencing will be more appropriate for specific learning categories and more generally for certain types of subject matter. The practical implication of this point to the design of CAI courseware is that no single strategy or sequence is likely to be suitable for all applications and that the choice of a particular strategy or sequence should follow from a careful task analysis and specification of objectives in terms of necessary learning skills.

2. Learner Variables in CAI.

Age is an obvious "who" dimension which must be accomodated across different tasks and means. In general, abilities (e.g., memory and attention span, conceptualization, reasoning,etc.), learning styles, motivations, interests, and attitudes all change with age.

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5. Furthermore, subjects which are relatively stable or static in nature (e.g., mathematics, statistics, physics, chemistry) and which include essential principles to be learned are probably more suitable for instruction via CAI than those subjects which are relatively fluid or dynamic (e.g., psychology, sociology, history) and which tend to be sensitive to interpretation. Of course, any single subject matter may have relatively stable and dynamic areas too.

Specifically, we know that young children have a definite visual and concrete orientation, i.e., they learn best (and prefer) information which is presented pictorially or iconically and in concrete forms. This means that subjects or tasks to be presented to young children should make liberal use of graphics and concrete examples for teaching concepts or principles. Furthermore, young children also have short attention and memory spans which means that relatively little information should be presented on each screen and that the transitions from screen to screen should be small in terms of the amount of new information introduced. Attentional prompts such as pointing arrows, flashing words, cartoon figures, etc., can be used in order to maintain a young child's attention. To compensate for attentional lapses, redundancy and overlap of content as well as frequent questioning or interaction should be used. Fast moving sequences and novelty are also useful ways to obtain and keep the attention of a young child.[6]

Older children (i.e., those who have become proficient readers) are much less dependent on iconic information and concrete examples and can utilize more symbolic and abstract information. However, there are still certain concept learning and problem solving abilities which are not fully developed until quite late in adolescence and many motivational/attitudinal developments come even later. For example, students do not typically become proficient at self-managed or self-directed learning until late adolescence (e.g., senior high school).

Special populations or groups of learners also require specific analysis with respect to unique characteristics. The most obvious cases are students with learning disabilities (e.g., deaf, blind, retarded) or groups who are considered disadvantaged (e.g., "inner city" students, native students). For students with disabilities, it is obvious that certain media and strategies will be inappropriate and hence that the appropriate means must be carefully selected. For example, a program for deaf children should make considerable use of graphics since this learner population is completely dependent upon visual information. Or for "inner city" students, the content may need to be carefully selected if it is to be meaningfully related to their experiences, attitudes, and motivations. The work of Suppes & Morningstar (1966) with the Stanford drill & practice program illustrates this point with respect to

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6. The television program Sesame Street is a good example of instructional design specifically aimed at young children and exemplifies most of these techniques (see Warren, 1976).

demographic variables. In terms of change in pre/post-test scores, the program was more effective with lower-class elementary students in Mississippi schools than the relatively affluent (and more achievement-oriented) students in California schools. Further on this point, Hess & Tenezakis (1973) compared the attitudes of "inner city" students toward CAI, teachers and textbooks, and found that CAI was rated more positively overall than either teachers or textbooks. Thus, CAI may be a more powerful and effective medium for certain learner populations because it provides positive feedback, is patient, interesting, consistent and fails to manifest sex or racial prejudices / biases.

Within any particular population or group, there are individual differences of all shapes and sizes to contend with. As is well known, the delivery of individualized instruction is one of the major rationales for CAI. However, at present no solid conceptual basis exists for the individualization of instructional parameters. The traditional approach has been the measurement of traits via psychometric methods (e.g., factor analysis). Aptitude x Treatment Interaction (ATI) research is an attempt to relate such traits to instructional "treatments". Table 1 suggests some possible relationships between certain well-known aptitudes and instructional parameters.

Insert Table 1 here.

Need achievement and (trait) anxiety are likely related to difficulty level and step size since research indicates that low, moderate and high difficulty have different effects on anxiety and achievement motivation. Inner-outer locus of control is a personality dimension which indicates an individual's self-perception of the extent to which they control their life or it is controlled by others. This dimension likely relates to the importance of learner versus teacher control in a course. Introversion/extroversion is a personality trait which characterizes the individual's social and value preferences. It is likely to affect the success of explicit feedback and motivators (in terms of intrinsic/extrinsic properties). Reflectivity/Impulsivity is a cognitive style which is likely related to the degree to which a student benefits from self-pacing and small versus large step sizes. It indicates the extent to which an individual will assimilate information. The cognitive style of levelers/sharpeners (closely related to field differentiation) describes the way an individual perceives and retains details, and their characteristic methods of organization. This likely interacts with the type of strategy used (e.g., inductive vs. deductive, serial vs. hierarchical). Specific ability dimensions (e.g., verbal

fluency, memory span, spatial scanning, etc.) can be related to instructional parameters such as step size, reading rate, preference for graphic/textual information, etc. Some of these suggested relationships have been documented by Stolurow (1972) in his proposal for instructional grammars.

For practical and theoretical reasons, the psychometric approach to individualization is unsatisfactory from an instructional design perspective. First, in order to make practical use of traits in subsequent instruction they must be measured via questionaires or tests which typically consist of hundreds of items and require at least an hour or more to complete if the instrument is to measure the trait reliably. Clearly, it is unreasonable to subject a student to a lengthy test battery preceding each course. [7] Secondly, psychometric tests are norm-referenced and designed primarily for classification/selection decisions (i.e., an individual's score in terms of relative position in the test-taking group). However, educational applications require criterion, domain or competency referenced instruments which specify in absolute terms the specific aptitudes or skills a student possesses (or lacks) in the domain of instruction. Since this issue has been presented elsewhere (e.g., Carver, 1974; Glaser, 1972; Merrill, 1975), I will not dwell upon it here.

Unfortunately the wholesale rejection of the traditional psychometric approach almost completely wipes the slate clean with respect to our understanding of individual differences. Clearly this is an unwanted consequence. One solution to this dilemma lies in restating trait constructs in terms of types and levels of learning outcomes (such as those used in Figure 3) which can then be used in the specification of objectives and selection of strategies. In this way, alternative ways of achieving the same objectives can be anticipated and accommodated in the instruction.

A second solution lies in adaptive programming, i.e., programming in which the performance of the student is used to adjust instructional parameters. This does not mean simply branching a student to different content based upon the number correct/wrong, but the actual change in strategies or modes of presentation, step size, difficulty level, etc. This entails building into the system, the

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7. This is probably not so unreasonable however, if the course is very long (e.g., 100 hours) and the measures are used throughout the course or if the same measurements can be used for more than one course.

capability to make inferences about student learning styles and abilities based upon both qualitative and quantitative performance information. An example of such adaptive programming is the work of Pask (1975). In a learner controlled program, it is possible to identify two general learning strategies: a serialist strategy which involves a linear, sequential choice of subtasks, and a wholist strategy which involves a top-down, multiple-track selection of subtasks. Pask has shown that students who learn via their non-preferred strategy perform poorer than those who use their preferred mode. Once identified (via monitoring), the structure of the task can be arranged to correspond to the style of the individual. Suppes & Morningstar (1972) have demonstrated that an adaptive "response sensitive" program, i.e., a program which keeps the student at an optimal level of difficulty, is more effective than a learner controlled logic.

A third and the most sophisticated suggestion for adapting to individual differences is the idea of maintaining a "student model" or representation of the student's present understanding of the subject matter or task (Self, 1974). Such a representation should map the skills which have been mastered by the learner onto the total domain of skills involved in the subject matter, thus indicating areas of understanding and deficiencies. In this approach, selection of material can be guided by the student's weaknesses and strengths -- each student can receive a truly individualized instruction which is based on the details of their prior learning. Such an approach in the area of teaching the programming language BASIC has been followed by Barr et al. (1976). It should be noted that this approach is presently only feasible with socratic or simulation strategies due to the limitations of current CAI software.

In this section on learner dimensions in CAI, we have discussed the interactions of task and means dimensions with with the learner variables of age, populations, and individual differences. While a number of different approaches to individualizing instruction were mentioned, it should be evident that this is still a very weak area of instructional design.

3. Means Dimensions in CAI.

We have already discussed the means dimension of strategies in terms of interactions with task variables. Control over the sequencing of instruction has been mentioned. There has been some research in CAI concerning the importance of allowing the learner to control various

instructional parameters, particularly pacing, type and modes of instruction (e.g., Newkirk, 1973; White & Smith, 1974). While there is some evidence that self-pacing may not always be an optimal strategy (e.g., Gropper & Kress, 1965) it seems that it is the most satisfactory alternative for most subject matters and learners. The PLATO system allows students to control the type of instruction via special control keys (e.g., "help", "lab",) provided this has been allowed for by the programmer. The TICCIT system allows the student to control the mode of instruction (rule, example, practice) as well as to select the sequence of instruction (see Bunderson, 1974). While the virtue of learner control features has not been adequately explored at present, the available research suggests that learner control will be most beneficial in the case of students who have a sophisticated knowledge of the subject matter or who have well-developed learning strategies and intrinsic reward structures.

Media research offers substantial literature on the relative importance of means variables which are relevant to CAI (see Briggs et al., 1967, or Levie & Dickie, 1973, for comprehensive and evaluative surveys).[8] Three major variables are the degree of realism in illustrations, the importance of color, the value of motion over still pictures, and choice of audio or visual modes. As far as the degree of realism in illustrations is concerned, it seems that simple line drawings are generally more effective than realistic schematics or photographs unless the realistic detail is essential to understanding or the student can study a realistic illustration for unlimited time. Color has generally been shown <u>not</u> to be more effective than monochromatic displays (black & white) in terms of performance; however, it has been shown that color is almost always preferred by students (particularly children) and hence may be valuable for its motivational properties. In addition, color used as a highlight or cue may be particularly important for students with poor discriminatory skills or poor visual ability. Dwyer (1976) has studied the interaction of degree of realism, use of color, and IQ. His results show that the effects of realism and color differ with the criterion measures and IQ levels, once again emphasizing the necessity of considering any instructional

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8. Some of the variables investigated in media research (e.g., motion) are not of immediate interest since they are not capabilities of current systems. However, future CAI systems will undoubtedly have the capability for motion (e.g., videodiscs) and hence these features will be important in CAI design.

variable in terms of the learner x task x means interaction.

Research on the importance of motion sequences over still pictures has shown that motion is particularly effective when the learning involves a co-ordinated sequence of actions or processes. With respect to the respective value of audio or visual modes of presentation, reading is generally found to be superior to listening because the reader can take advantage of the greater duration (referability) of printed text. However, young children learn better from verbal presentations until they have developed reading proficiency. There are also the obvious tasks (e.g., foreign langauge learning, music) which will require considerable audio presentation. With respect to the simultaneous presentation of audio and visual information, redundant information on both channels tends to be facilitative while simultaneous presentation of different information on both channels results in interference since only one sensory mode can be attended to at once.

Two general means dimensions of concern to CAI are the use of graphics and typography. Graphics includes the use of illustrations such as graphs, sketches, flowcharts, diagrams, as well as underlining or boxing of important ideas, arrows to indicate connections, variable size letters for emphasis, etc. Typography concerns the organization and layout of text in terms of size of print, typefont, spacing, indentation, justification, page size, etc. Little (if any) research has been conducted to investigate the parameters of either graphics or typography specifically in CAI systems.

We have already discussed the importance of the liberal use of graphics for young children and certain learner populations. However, there are two general reasons for using graphics. First, iconic information is often essential for showing complex interrelationships and developing an intuitive understanding of a concept or principle. Graphics are commonly used in the physical sciences, mathematics and statistics, economics and sociology for these reasons. Secondly, graphics are generally motivating and attention focusing (in support of this point, we can refer to the use of graphics in advertising). This is particularly evident in the case where graphics are used to deliberately highlight or emphasize basic concepts, principles, or definitions. Finally, there is the point that the same information presented in different graphic forms can convey different meaning to the student. Thus as a remedial measure, alternative graphical presentations conveying the same idea are probably helpful. In fact, alternate graphics for the same idea may be more useful than a verbal paraphrase of the same idea in written text (a usual remedial procedure). A good discussion of interactive computer graphics is given by

Bork (1976).

Typographical research is concerned with the factors which affect the legibility of printed text and hence the ease, speed and accuracy of reading. The following are some selected research findings from typographical research:

* text in capital letters or italics is read slower than lowercase
* certain typefonts inhibit reading speed
* for a particular size of type and typefont, there is an optimal interline spacing (generally no spacing and too much spacing slow down reading speed)
* in terms of the color of print and backgrounds, the brightness contrast is the most important characteristic
* glazed or shiny paper texture inhibits reading speed
* curvature decreases legibility
* unjustified text is more legible for short lines; justified text allows longer line lengths

It is probably the case that many of the factors known to affect the legibility of text are relatively inconsequential for mature readers under most reading conditions; however they may result in serious hindrances to young children and special groups of learners (e.g., retarded) and hence be very important considerations for these students. The fact that capital letters retard reading speed suggests that terminals which do not have the capability for lower-case characters are unsuitable for CAI courses which require extensive reading. Because CAI authors typically design their own typographic layouts (with respect to line width, inter-line spacing, justification, use of capitals and italics, etc.), it is clearly important that they be knowledgable about the effects of typographical variables. Tinker (1965, Part 3) provides a good introduction to typographical variables and comprehensive bibliographies of research are given by Hartley et al. (1974) and Tinker (1966).

We have considered a number of means dimensions including strategies, learner control, various media, graphic and typographic variables. While some recommendations were made, very few of these recommendations are made on the basis of research done within a CAI context. Until such research is conducted, such recommendations will remain very tentative in nature.

4. The Instructional Design Cycle in CAI Activity.

Recall that there are 5 major stages or phases in the instructional design cycle (depicted in Figure 2). The first

stage involves the identification of educational needs and goals. CAI activity is dedicated to the belief that individualized instruction is a desirable and important educational goal and further, that the computer delivery of instruction is a very effective means of achieving this goal. However, it is necessary to recognize that other educational goals exist and ones which CAI may not be able to contribute toward. For example, socialization (i.e., the ability of an individual to successfully interact with others) is considered by most to be an important educational goal. This skill is acquired more or less inadvertently within the traditional classroom mode of instruction by virtue of the fact that the classroom provides a social learning situation. Strict individualization of instruction as could be achieved with CAI would not contribute toward this goal.

As far as the specific content of what is to be taught (e.g., basic skills versus diverse curricula, for instance), CAI does not really imply any particular commitment. [9] However, the selection of CAI as the instructional medium or methodology does mean that students will need to adopt some degree of "computer literacy" (even if this is simply learning how to use a terminal). This represents a subtle educational goal or value judgement, namely that the ability to interact with a computer program is a desirable educational experience. In general, most (but not all) would agree that this is a worthwhile component of a contemporary education.

It is also necessary to recognize that different goals and needs exist for various groups. Students have particular needs (e.g., self-actualization, creative desires, etc.) which a CAI system must satisfy. Authors designing CAI courses also have certain goals and needs (e.g., a programming language which is easy and powerful; recognition of their work, etc.) which also must be met. Educational administrators have another set of needs and goals which stem from economic and organization concerns. Finally, the general public (parents, politicians, businessmen) have expectations about the quality and results of instruction (e.g., accepted levels of reading and writing competency). In many cases, the needs or goals of different groups will conflict and resolutions must appeal to some higher-level

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9. Historically it is true that mathematics and physical sciences have dominated the type of instruction presented via CAI. However, this picture is rapidly changing as the professions, social sciences and humanities become increasingly aware of computer methodology.

notion of the purposes of education.

The consideration and synthesis of all of these goals/needs and their practical translation into something specific enough to be taught rests mainly in the hands of the CAI author. Many authors will design courses with very vague notions of instructional objectives while others will work with quite specific behavioral statements. [10] In addition to the skill of the author at task analysis, the statement of objectives will also depend (you should be reacting automatically with this by now) upon the nature of the task and the learners. Thus, some tasks and learners are relatively easy to derive objectives for, others are difficult. However as should be clear from the preceding discussion, the degree of precision achieved in selecting the appropriate means of instruction will depend heavily upon the precision with which the objectives are specified. A crude learner and task analysis will lead to a crude choice of instructional means. In traditional, lock-step classroom instruction this may well be unavoidable; in CAI it is not. None-the-less, CAI is often used crudely.

In terms of realizing instructional objectives in CAI, it is necessary to ensure that the skills indicated by the objectives are taught and that they are appropriately evaluated. The relationships between the various types and levels of skills and the selection of strategies in CAI have already been discussed.

Preparing instruction in CAI revolves around the flexibility, power and ease of use of a particular author language and associated CAI system. Important factors here involve whether authoring can take place on-line or not, the availability and power of text-editing features, procedures for graphic definitions, and the specific capabilities of the author language with respect to defaults, implicit branching, etc. Zinn (1974) has discussed the desirable characteristics of authoring systems. In addition to the nature of the author language, there is also the capability

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10. Often those naive to CAI assume that because something is programmed on a computer, the instructional objectives must have been specified very clearly. While it is true that in order to program something, every step in the instructional sequence must be made explicit, it is still easy enough to specify a very detailed sequence of instruction which doesn't achieve any particular objectives. The use of CAI ensures that the instruction will be replicable but unfortunately does not guarantee that objectives will be specified and evaluated.

of the system itself to be considered. This includes the availability of audio-visual, psychological, and instructional specialists and programmers, system availability, response time and reliability, the number, type and location of student terminals, etc. Both the author language and the system features provide constraints on the instructional means which may be used in the design of a course.

The evaluation stage of instructional design in CAI offers considerable improvement over this stage in non-CAI applications. The reason for this is that CAI allows for the complete, automatic, and unobtrusive monitoring of all student performance. These data provide a detailed summary of a student's learning history for the purposes of student evaluation and at the same time, information on the effectiveness of the instruction across all students. From these data, it becomes possible to pinpoint particular students who are having difficulties and the specific nature of these difficulties. It also points out instructional sequences which are ineffective and need to be revised. Thus the feedback cycle between evaluation and the previous two stages is explicitly provided for in a CAI system. This capacity to empirically monitor the success of instruction is a major reason why CAI represents a sensitive instructional technology and one in which the value of instructional design can be systematically demonstrated.

The last stage, implementation, is currently a thorny one in CAI development because of the complex technical, economic, and political problems involved. Technical problems involve the appropriate selection of suitable hardware (e.g., a dedicated versus shared cpu, terminal types), software (range, power, flexibility), and the distribution and transfer of developed courses (copyright, standardization). Economic problems center around the costs of hardware, instructional programmers and system support staff, and the large amount of time required to author a course (time=money). While the relatively high cost of CAI is currently a major obstacle to its widespread use, this problem will likely become minor as the eventual cost of hardware becomes negligible (software costs will remain, however). Political problems include the opposition from teachers who see their role as major providers of instruction being threatened, the change in academic power structure created by CAI facilities, and ignorance on the part of general public and politicians regarding the nature and impact of computer education. A good discussion of political problems encountered in CAI is given by House (1974).

With regard to the feedback cycle between the

implementation stage and the initial stage of goal definition, only a few CAI systems have existed long enough for any implementation effects to be assessed. It is possible to offer a few speculative guesses about such effects. For example, once students have been exposed to intensive, individualized, and interactive instruction on a regular basis, it is likely that they will come to expect and perhaps demand this quality of instruction. Another possibiliy is that after considerable long-term exposure to individualized instruction, students will have a definite need for socialization experiences which are no longer provided by classroom interaction. It is also possible to speculate upon the more general and profound effects on the educational system and society at large (e.g., the re-education of teachers to be instructional designers, programmers, etc.).

The preceding discussion of the different stages in the instructional design cycle has highlighted some of the considerations in the application of instructional design within a CAI context. It illustrates how the three major components of instructional design (i.e., task, learner, and means analysis) fit into an overall pattern and furthermore, the importance of the factors involved in the identification of goals, evaluation, and implementation which influence the overall success of instruction. To make an analogy with the design of a car -- the car can be carefully designed and engineered but the fact that the car requires fuel and that it pollutes the environment or that it is sloppily assembled in the factory will result in a product of questionable social or personal worth. Similarly, the ultimate utility of instructional design (in a CAI context or otherwise) rises or falls with the entire educational system of which it is part.

III. Conclusions.

The preceding discussion has emphasized that the selection of the appropriate instructional means must be determined by the relevant learner and task dimensions. A consequence of this point is the fact that the instructional designer needs to adopt a pluralist philosophy with respect to the utilization of different methods and media. No single technique can be expected to apply to all tasks and learners. Thus the delivery of effective instruction requires the facility to employ different strategies, media, and methods. CAI provides the instructional designer with this facility for it is neither a medium nor methodology -- it encompasses many media and methods.

The major advantage of carrying out instructional design in a CAI context is that CAI provides a suitable environment for the systematic delivery and evaluation of instruction. Because instruction is programmed, the computer code represents an explicit and reproducible form of the actual delivery (not just the content). Because student performance data can be collected and processed automatically, the quality and effectiveness of the instructional design can be constantly monitored. Because instruction is individualized, the appropriate learner variables can be accomodated. Because all delivery media are integrated and synchronized, the proper co-ordination of media is ensured.

However it would be wrong to leave the impression that CAI guarantees effective instructional delivery for three major reasons. First, without adequate instructional design, the use of CAI can be like using a supersonic jet to spray farm crops. In fact because of its power, poor CAI instruction probably has greater potential for harm than other instructional approaches. Secondly, there are certain tasks, skills, or learners with which CAI may not be the best approach. The specific case of motor skills has already been mentioned. Thirdly, the details of how certain instructional variables interact or their effects in a CAI context are simply not known. Needed research has been alluded to in many parts of this report.

Early in the discussion, instruction was contrasted with teaching and learning. It is likely that the use of the computer in education will eventually dissolve this distinction. As computers become widely used for clerical and administrative functions, counselling and guidance, and even personal uses, the distinction between instruction and teaching will become fuzzy and disappear. Although it has not been emphasized herein, CAI is also very important as a tool to investigate learning processes and to test

theoretical notions about human learning. (Of course, any prescription for instruction is either based upon or constitutes a hypothesis about learning processes.) CAI brings together the delivery of instruction and research in learning in a way that is not possible when teaching and learning research are separate activities. It is hoped that the tremendous power and sophistication that the computer permits for instructional design will be carried over to other education domains.

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APPENDIX I.

This appendix gives a brief description of each of the 7 major strategies commonly used in CAI along with references to work which exemplifies this strategy. Keep in mind that any particular course will often combine a number of these strategies.

1. Drill & Practice. This involves simply the presentation of a problem followed by an appropriate correct/incorrect message. No instruction is involved. The best examples are the Stanford programs in arithmetic and reading (see Atkinson, 1974; Suppes & Morningstar, 1972).
2. Tutorial. A tutorial strategy involves a general three stage sequencee: the presentation of concepts/principles, testing, and the branching to further instruction based upon the answer analysis. Most of the PLATO courseware utilizes a tutorial strategy.
3. Exploratory. An exploratory strategy involves providing the student with suitable means (e.g., a programming language) and then allowing them to invent/discover their own problems and solutions. This type of strategy is described by Dwyer (1974), Papert & Solomon (1972) and Peele (1974).
4. Simulation. In this strategy, a model of a system, process, or activity is provided which allows the student to alter the parameters and observe the results. The best known and most successful examples are the Huntington Project simulations written in BASIC.
5. Socratic. The socratic strategy involves providing instruction in a dialogue (question and answer) fashion. The central notion is to force students to reason for themselves. The best examples are the SCHOLAR and SOPHIE programs both described in Bobrow & Collins (1975).
6. Case Studies. A case study strategy involves the descriptive presentation of a situation which illustrates a particular pattern or configuration of variables. The CARE (Computer Assisted Remedial Education) programs originating from Pennsylvania State University utilize case studies frequently.
7. Games. A game strategy is basically intended to entertain and usually involves competition between the student and the computer to win (e.g., tic-tac-toe, spelling quiz, space war, etc.). A description of many games written in BASIC is given in Ahl (1975).